THE SURGICAL TREATMENT OF THE MORE. COMMON TYPES OF DIAPHRAGMATIC HERNIA: ESOPHAGEAL HIATUS, TRAUMATIC, PLEUROPERITONEAL HIATUS, CONGENITAL ABSENCE AND FORAMEN OF MORGAGNI*

REPORT OF 404 CASES

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ALTHOUGH THE OCCURRENCE of herniation of abdominal viscera through the diaphgram is relatively uncommon when compared with herniation through the abdominal wall, there are more different kinds of hernia occurring through the diaphragm than there are occurring through the other walls which encase the abdominal contents. The reason for the different types of diaphragmatic hernia is the unusual embryologic formation of the diaphragm, which makes it more susceptible to weak areas through which these herniae may occur.

The formation of the diaphragm from embryonic structures is a highly complex process, because the muscular elements of the diaphragm are derived from several sources. The anterior, lateral and central parts, which comprise the greater portion of the diaphragm in the adult person, are formed from the transverse septum and fused ventral mesentery. The remaining, postero-lateral portion is formed by the fusion of the dorsal mesentery and the mesoderm derived from the receding wolffian body with the pleuroperitoneal membrane derived from the pulmonary ridge. It is difficult to determine the exact amount of the muscle tissue that is derived from each of these structures, since considerable variation probably occurs during the process, but it is likely that the dorsal mesentery forms the posterior and central portions, which contain the esophageal opening. The mesodermal cells from the receding wolffian body form the right and left crura. The pleuroperitoneal membrane grows ventrally, closes the remaining opening (hiatus pleuroperitonealis) between the peritoneal celom and the pleural celom by fusion with the transverse septum and forms the lateral portion of the diaphragm.

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the fissura pleuroperitonealis (foramen of Bochdalek) and also through the outer crus and through the esophageal opening. Herniation through the

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dome is common but cannot be explained on the foregoing basis, because the dome, embryologically, is not a fusion region. Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuro-peritoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

CLASSIFICATION OF DIAPHRAGMATIC HERNIA

There are numerous classifications of diaphragmatic hernia which are based on the embryologic and etiologic aspects, pathologic anatomy, the site of the opening in the diaphragm, the presence or absence of a sac, the contents of the hernia, and other factors. It is difficult, or impossible, to make most of these classifications clinically; accordingly, many of them are of little practical value.

All types of true hernia have a sac as one of the component parts; so that many conditions, commonly included under this term but in which there are no hernial sacs, would more properly be termed "evisceration" or "false hernia." The presence or absence of an hernial sac cannot be determined by clinical examination. It can be found only at operation.

From a clinical and surgical standpoint, the history of a preceding injury is helpful in establishment of the diagnosis and in determination of the type, urgency and prognosis of the operative treatment. Because of the practical clinical and surgical significance of trauma as an etiologic factor, I have suggested that diaphragmatic hernia be classified into two main groups: Nontraumatic and traumatic. I have subdivided these two groups according to the various types.

Nontraumatic Hernia.—A nontraumatic diaphragmatic hernia may be congenital or acquired. If it is congenital, the hernia is attributable to embryologic deficiency and usually does not have an hernial sac. The most common sites of a congenital hernia, in the probable order of frequency of occurrence, are: (1) Through the hiatus pleuroperitonealis (foramen of Bochdalek); (2) through the esophageal hiatus; (3) through an anterior substernal opening (foramen of Morgagni or Larrey's space); and (4) through the gap left by partial absence of the diaphragm, a gap which is usually situated in the posterior portion of the muscle.

If the hernia is acquired after birth, the sites of occurrence are: (1) Through the esophageal hiatus, a type in which there is an hernial sac; (2) through the region of fusion of the anlage of the diaphragm; and (3) at sites named under the congenital type in the foregoing paragraph.

Traumatic Hernia.—Traumatic diaphragmatic hernia may be caused by direct or indirect injury or by inflammatory necrosis of the diaphragm. In case of indirect injury of the diaphragm, the hernia may occur at any point, including points of embryologic fusion, but the most common sites are the dome and the posterior half of the left part of the diaphragm. On the other

hand, the hernia may occur in the right part of the diaphragm. It usually is the result of a severe, crushing injury. When the hernia occurs through the esophageal opening there is a sac but when it occurs through the leaf of the diaphragm there usually is no sac. In case of direct injury of the diaphragm, the hernia may occur at any point and is usually the result of penetrating wounds, such as those inflicted by a gun or knife.

Rupture of the diaphragm may be the result of inflammatory necrosis, which, in turn, has been caused by subdiaphragmatic abscess. Again, rupture may follow necrosis caused by drainage tubes which have been introduced into empyematic cavities. In these cases the opening usually is situated in the posterior part of the diaphragm and there is no hernial sac.

CLINICAL AND SURGICAL CONSIDERATIONS

In my experience, the most common types of diaphragmatic herniae, in order of frequency, which require surgical treatment are esophageal hiatus hernia; herniae due to trauma, indirect or direct, or to inflammatory necrosis; absence of a portion of the diaphragm; hiatus pleuroperitonealis herniae and herniae through the foramen of Morgagni (Fig. 1).

The number of diaphragmatic herniae of each of these types in the 404 cases in which I have operated is shown in Table I. Each of these various types of diaphragmatic hernia presents different clinical manifestations as well as different methods of surgical treatment. It will not be possible to go into detail but I shall present some of the more important clinical and surgical considerations of these different types of diaphragmatic hernia.

The clinical recognition of diaphragmatic hernia on the basis of the subjective symptoms alone is often very difficult. The symptoms are complex because of the various structures involved in the hernia and depend on the amount of mechanical interference with the function of the herniated abdominal viscera, on the degree of impairment of the normal function of the diaphragm and on the amount of increased pressure within the thorax which causes impairment of respiration and circulation.

The clinical syndrome of diaphragmatic hernia may be divided into two main groups. The first group occurs in cases in which the stomach is the only abdominal organ involved in the hernia. The symptoms are those of intermittent and usually progressive incarceration and obstruction of the stomach. The most common type of diaphragmatic hernia in which the stomach is the only abdominal viscus involved is through the esophageal hiatus. However, this type of hernia may contain various portions of the omentum, depending on the amount of stomach involved in the hernia. Inasmuch as these herniae are progressive, the entire stomach may become involved in the hernia and in these herniae the colon may also become incorporated in the hernial sac because of its attachment to the greater curvature of the stomach. More rarely the spleen may become involved because of its attachment to the cardia of the stomach. In these cases, in

TABLE I

DATA IN 404 CASES OF DIAPHRAGMATIC HERNIA IN WHICH OPERATION WAS PERFORMED

Site of Opening	Cases	Cause	Contents of Hernia	Cases
Esophageal hiatus	287	Congenital (history of trauma, 17)	Stomach (omentum)	266
			Stomach, omentum and spleen	6
			Stomach and colon	15
Short esophagus type	33	Congenital (11)	Stomach only	33
Hiatus pleuroperitonealis	9	Congenital	Right colon and small bowel	4
			Colon, small bowel, stomach and spleen	4
			Colon, small bowel and appendix	1
Absence of posterior fourth of diaphragm	12	Congenital	Stomach, colon, small bowel and spleen	5
			Small bowel and colon	2
			Small bowel, colon, spleen, appendix (3) and stomach (1)	5
Foramen of Morgagni (subcostosternal)	8	Congenital (right diaphragm 6; bilateral, 1)	Colon and omentum	7
			Stomach and colon	1
Traumatic: Left diaphragm	54	Trauma (indirect injury, 36; direct injury, 8)	Stomach only	7
			Stomach and colon	12
			Stomach, colon, small bowel (30), spleen (20) and liver (12)	35
		Inflammatory necrosis (6)		
Right diaphragm	1	Trauma (direct)	Stomach, colon, small bowel, liver (gallbladder) and head of pancreas	1
Total	404			404

TABLE II

SURGICAL PROCEDURES AND OPERATIVE RESULTS IN 404 CASES

Radical repair of defect in diaphragm:
  Approach: Abdominal, 369; thoracic, 2.. 371
Preliminary interruption of phrenic nerve....................................... 268
Preliminary extrapleural thoracoplasty................................ 3
Operations in conjunction with repair of hernia:
  Gastric resection for gastric ulcer, 1; for carcinoma, 2................................ 3
  Closure of perforated gastric erosion, 2 (Total erosions, 37)............................. 2
  Gastro-enterostomy for gastric ulcer, 1; for duodenal ulcer, 2...................... 3
  Splenectomy for tuberculosis, 2; for injury, 8.. 10
  Appendicostomy for obstruction....................................... 1
  Appendicectomy for appendicitis.. 2
Interruption of left phrenic nerve (hiatus hernia):
  Palliative, 7; therapeutic, 26.. 33

      Total patients operated upon.. 404
Recurrence of hernia of all types after operation:
    Traumatic hernia, 0; congenital defect, 1; esophageal hiatus, 9
Recurrence of esophageal hiatus herniae, 9
    Roentgenologic diagnosis, without recurrence of symptoms, 5
    Roentgenologic diagnosis, with recurrence of symptoms, 4; repair of recurrent herniae, 4
Operative deaths, 16 or 4.0% (basis of 404 patients operated upon)

which the colon is involved, there may be additional symptoms of partial or
complete intestinal obstruction.

The second group consists of those cases in which multiple abdominal
viscera are involved in the hernia. These herniae are usually of traumatic
origin and are caused by laceration of a normal diaphragm. However, they
also may be of congenital origin and may result from congenital structural
deficiency of the diaphragm. The symptoms in these cases are more varied
and severe than those in the first group because of the multiple structures
involved and are often more acute in onset. The initial symptoms may be
those of acute intestinal or gastric obstruction or severe hemorrhage.
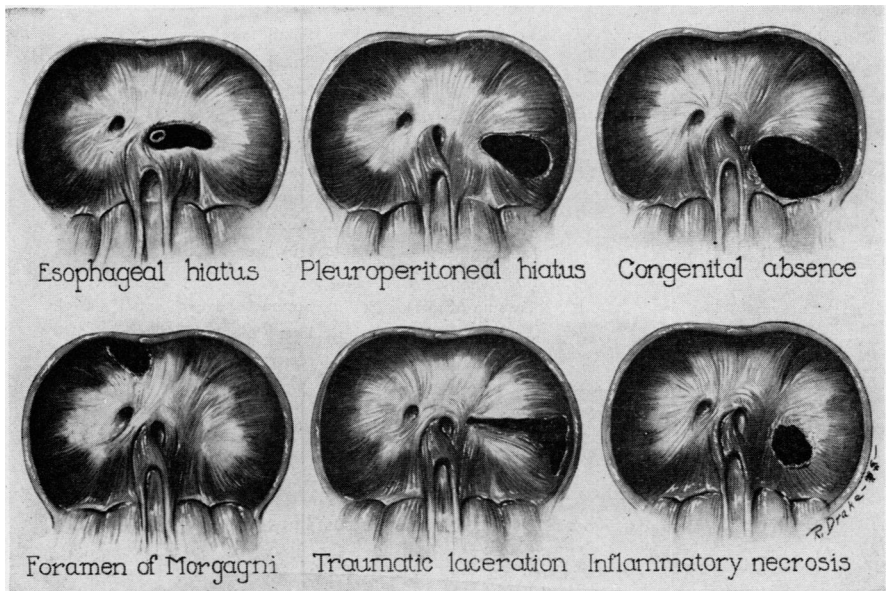
FIG. 1.—Situations of congenital structural defects and traumatic lacerations of the diaphragm which
cause the more common types of diaphragmatic hernia.

From the standpoint of treatment, diaphragmatic hernia is primarily a
mechanical condition and the only treatment which will relieve the condition
is operative repair or reconstruction of the abnormal opening in the diaphragm
after replacement of the herniated viscera into the abdomen. The indications
for surgical intervention and methods and technic of surgical procedures
depend on the type, situation and size of the defect in the structure of the
diaphragmatic muscle, the kind and amount of abdominal viscera involved
in the hernia and whether or not the viscera are enclosed in the hernial sac.

In the treatment of all herniae that have occurred through the left portion
of the diaphragm, I prefer the abdominal approach by means of an oblique
left rectus incision, starting at the ensiform cartilage and extending to the
outer border of the rectus muscle. I believe there is less risk of the occurrence
of thoracic complications when this approach is used. It is of particular advan-
tage in cases of esophageal hernia, for the herniated stomach is usually

confined in a sac in the posterior part of the mediastinum and does not enter the true pleural cavity.

In the repair of herniae through the right portion of the diaphragm, I prefer the thoracic approach because the large, right lobe of the liver makes the abnormal opening in the diaphragm inaccessible from the abdominal approach.

The technical difficulties of adequate exposure of the hernial openings through the left portion of the diaphragm and the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of these hernial openings is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the wound. The spleen is often very adherent to the posterior part of the diaphragm and hernial openings, but usually can be separated from these structures by blunt dissection. In some instances the spleen has been so traumatized by the injury, and so bound into its abnormal position by adhesions, that it cannot be separated from the hernial opening without seriously injuring it. This not uncommonly occurs in the traumatic types of hernia, and occasionally in esophageal hiatus hernia. In these cases splenectomy is necessary.

Paralysis of the diaphragm, produced by temporary or permanent interruption of the phrenic nerve, is of value as a procedure preliminary to radical operative repair of esophageal hiatus herniae. It is a necessary procedure in the surgical treatment of partial thoracic stomach resulting from a congenitally short esophagus. In some cases in which radical operative repair is contraindicated, it may be used as a palliative measure.

ESOPHAGEAL HIATUS HERNIA

Herniation of the abdominal viscera through the esophageal hiatus is the most common type of diaphragmatic hernia occurring in adult life. These herniae are of considerable general interest because of the relative frequency of their occurrence, their indefinite causation, the variation of the relationship between the defective esophageal hiatus and the structures involved in the hernia, the progressive character of their development, the varied and complex symptoms produced by them and because of their treatment, which may be conservative if the herniae are small and symptoms mild but which may embrace surgical treatment if the herniae are large.

The symptoms of esophageal hiatus hernia may begin at birth or at any time during later life. Because of the progressive character of this type of hernia, the symptoms vary as the hernia becomes larger, depending on the degree and type of herniation present. Therefore, several different clinical diagnoses can be made in the same case, depending on the time at which the patient is examined, because of the changing symptoms. Accordingly, the condition may be termed the "masquerader" of the upper part of the abdomen. This, I believe, is the most important clinical consideration of

esophageal hiatus diaphragmatic herniae. In a study of 320 cases of this type of hernia in which I have performed operations, it was found that an average of three previous erroneous clinical diagnoses had been made in these cases before the correct diagnosis was established. The most common
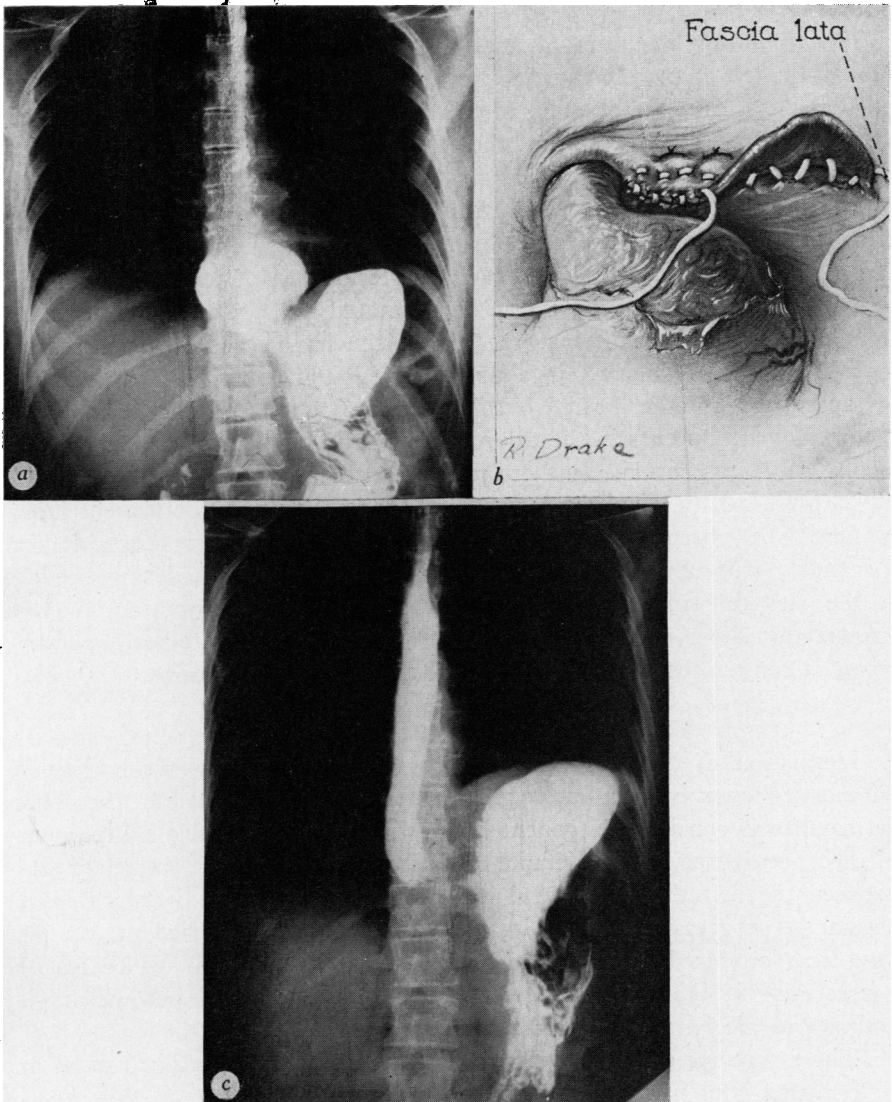

FIG. 2a.—Patient, age 49. Esophageal hiatus hernia with herniation of the cardiac end of the stomach through the esophageal hiatus and some displacement of the lower part of the esophagus (previously diagnosed gallbladder disease).

b. Same patient. Enlarged esophageal hiatus repaired to the left of the esophagus with interrupted silk sutures and continuous sutures of fascia lata by lapping the anterior over the posterior margin of the opening.

c. Same patient three weeks after repair of the hernia. The entire stomach is below the diaphragm, which is elevated because of temporary interruption of the phrenic nerve. The esophagus is in normal position.
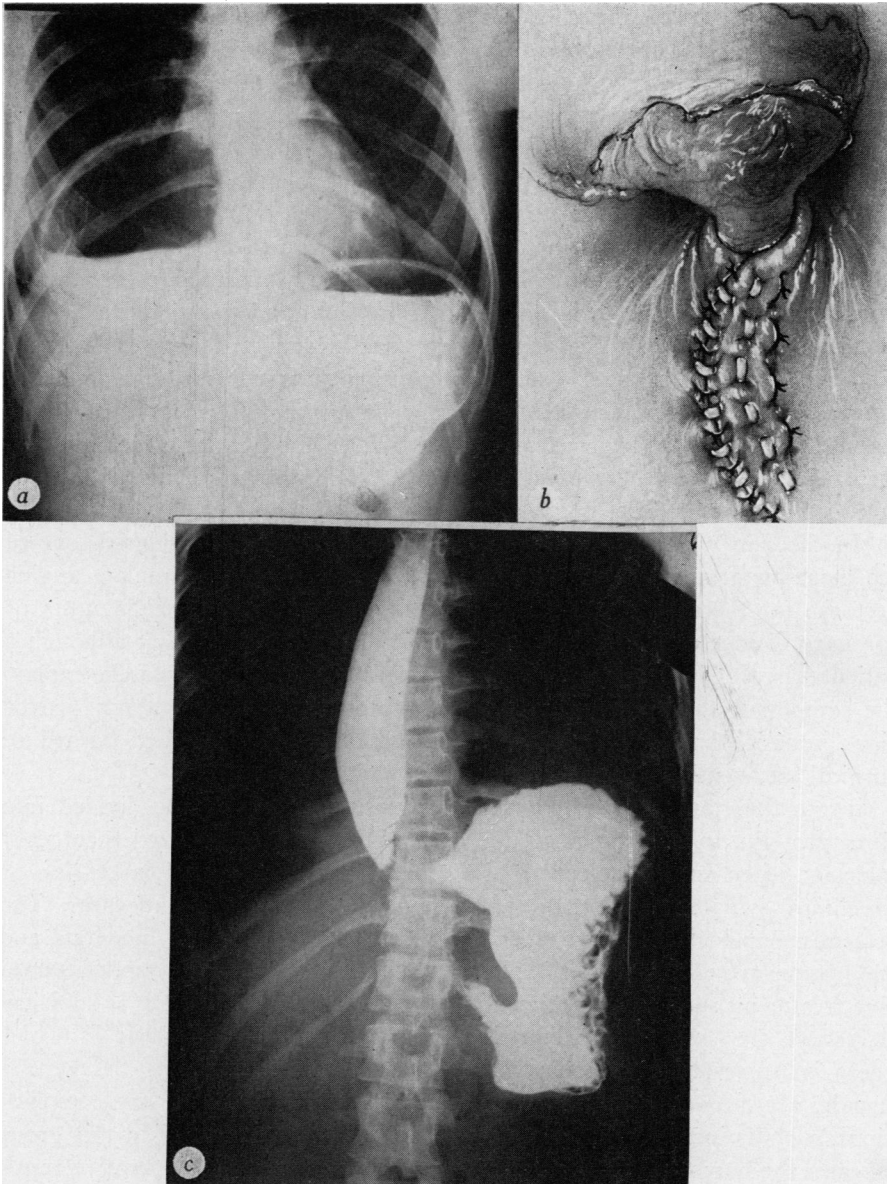
FIG. 3*a*.—Patient, age 17. Esophageal hiatus hernia with herniation of the pyloric two-thirds of the stomach into the right thoracic cavity. Stomach is enormously dilated due to incarceration and obstruction (previously diagnosed ulcer with obstruction).

b. Same patient. The enlarged hiatus, defective posteriorly, is repaired with interrupted silk sutures and continuous sutures of fascia lata by overlapping laterally in front of the aorta.

c. Same patient on dismissal, showing the entire stomach, in normal position below the diaphragm, which is elevated as result of temporary interruption of the phrenic nerve. The esophagus is in normal position.

erroneous diagnoses, in order of frequency, were found to be cholecystitis, cholelithiasis, gastric ulcer, duodenal ulcer, hyperacidity, secondary anemia, cardiac disease, carcinoma of the cardia, stricture of the esophagus, appendicitis and intestinal obstruction. In 32 of these cases the patients had been operated upon previously for other conditions, without complete relief of symptoms. They were completely relieved after repair of the hernia (Fig. 2).

The chief symptoms of esophageal hiatus hernia are pain, distress, gaseous eructation, vomiting, dyspnea, hemorrhage, weakness, anemia and palpitation of the heart. At the onset the symptoms are usually mild; they consist of epigastric distress that is projected through to the back and which comes on in the course of, or shortly after, a heavy meal. However, such attacks may be brought on by taking anything into an empty stomach, such as a cupful of coffee. The attacks are usually similar to one another in character but vary a great deal in intensity, depending on the amount of stomach that becomes incorporated in the hernia and the degree of interference with the diaphragm as well as the size of the hernial orifice and the occurrence of associated complications such as traumatic ulcer and incarceration of the stomach (Fig. 3).

In cases in which surgical treatment of the hernia is considered, one of the most important groups is that in which the symptoms simulate angina pectoris, for there are often no definite findings on which the diagnosis of coronary disease can be established. It is to be remembered that although a patient has a definite esophageal hiatus hernia that could adequately explain the symptoms, the patient can also have coronary sclerosis without proved signs and, if this condition is present, it constitutes a marked hazard to surgical intervention for the hernia.

From the standpoint of management hiatus hernia may be divided into three groups: In the first group the hernia is small, is recognized roentgenologically, often during the course of a general examination, and causes few or no clinical symptoms. No treatment is indicated in this group of cases. The second group includes those cases in which the symptoms are moderate and the herniae are of moderate size; in many of the cases in this group, conservative treatment, such as regulation of diet and reduction of weight, is sufficient to relieve the symptoms. The third group includes those cases in which there is no response to conservative measures; in these cases the herniae usually are large, and in many cases, in my experience, there are complications, such as incarceration of the stomach or gastric erosion. In this group of cases the only treatment that assures relief of symptoms is operative repair of the hernia.

In all cases in which a third or more of the stomach is involved in the hernia, surgical intervention should be considered, because the condition is progressive and usually the progressive enlargement becomes more rapid after the hernia has attained this size. Operation should be performed before severe incarceration, with consequent obstruction and traumatic lesions of the stomach, has occurred. The operative risk is increased by gastric reten-

tion and the technical difficulties are enhanced by fixation of the stomach to the diaphragm and to the hernial sac within the thorax. In all cases in which the colon is involved in the hernia, early operation is necessary because of the danger of occurrence of intestinal obstruction.
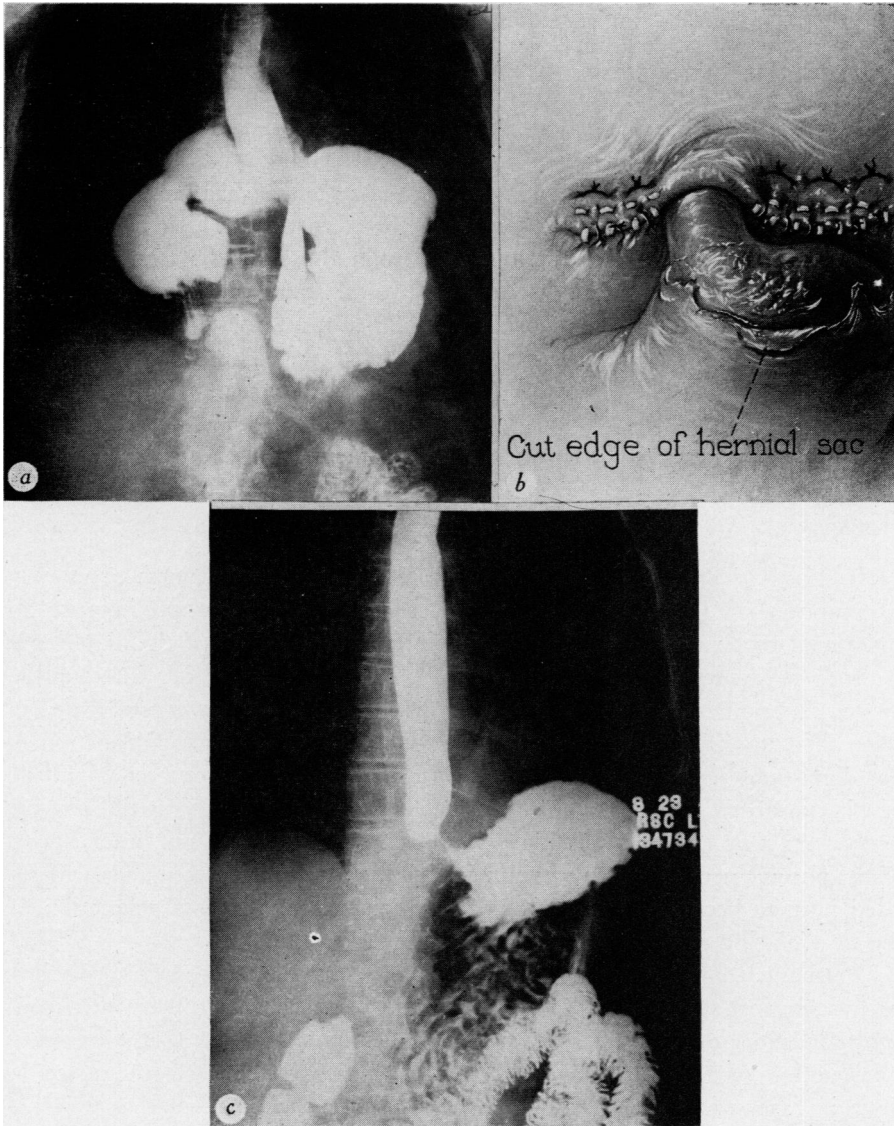

FIG. 4a.—Patient, age 55. Esophageal hiatus hernia with herniation of the entire stomach, which is inverted, and of a portion of the duodenum, with marked elevation of the esophagus and also herniation of the transverse colon through the esophageal hiatus.

b. Same patient. Repair of the markedly enlarged esophageal hiatus by overlapping the anterior margin over the posterior margin on both sides of the esophagus and at a higher level on the esophagus. Interrupted silk sutures and continuous sutures of fascia lata were used in the repair.

c. Same patient three weeks after repair of the hernia, showing the entire stomach in normal position below the diaphragm, which is slightly elevated as a result of interruption of the phrenic nerve. The esophagus is in normal position and extends to the diaphragm.

While all herniae through the esophageal hiatus are considered under the general term "esophageal hiatus hernia," there are three different types which are important from the standpoint of surgical technic. The first type consists of those cases in which the esophagus maintains its attachment to the diaphragm and the cardiac end of the stomach has herniated through the abnormal opening along the side of the esophagus. This is commonly called a para-esophageal hiatus hernia. It is, however, relatively infrequent and does not constitute more than 20 to 25 per cent of cases in which the patient comes to surgical treatment. The second type consists of those cases in which the esophagus is markedly retracted or shortened into the mediastinum but in which it is long enough to reach the diaphragm by traction. This type constitutes 75 to 80 per cent of cases in which treatment is surgical. The herniae are usually larger than those of the first type and the results are not as favorable from a surgical standpoint, for recurrences are more prone to develop because of the difficulty of reëstablishing fixation of the lower part of the esophagus to the diaphragm. The third type is that of the true short esophagus with partial thoracic stomach, which may also include cases of cicatricial contraction with fixation of the esophagus. These cases present an entirely different surgical problem from the true esophageal hiatus hernia.

SURGICAL TREATMENT

In most cases of esophageal hiatus hernia, I prefer to perform temporary interruption of the phrenic nerve by crushing the nerve preliminary to abdominal repair of the hernia because permanent paralysis of the diaphragm is rarely necessary in this type of hernia. Following temporary interruption of the phrenic nerve the function of the diaphragm is usually reëstablished in from three to six months. In cases in which reëstablishment of function of the diaphragm is not desired because of the danger of recurrence of the hernia, paralysis can be made permanent by cutting or evulsing the phrenic nerve. As a procedure preliminary to radical surgical treatment, interruption of the phrenic nerve is often of value in treatment of incarcerated and strangulated herniae because it prevents spasm of muscle and causes relaxation of the hernial ring.

Permanent interruption of the phrenic nerve may be a necessary procedure in the surgical treatment of partial thoracic stomach resulting from a congenitally short esophagus. However, I wish to emphasize that permanent interruption of the phrenic nerve is rarely necessary and should never be done in cases of hiatus hernia until it is definitely ascertained that it is not advisable to reëstablish the function of the diaphragm. It should be emphasized also that this procedure cannot replace the operative repair of the hernia. It is important to bear in mind that the atrophy of the diaphragmatic muscle which follows permanent interruption of the phrenic nerve may make it impossible to obtain a satisfactory result in the event of further radical repair of the hernia.

RADICAL SURGICAL REPAIR

I prefer the abdominal approach in all cases of esophageal hiatus hernia because the herniated viscera are contained in a sac in the posterior mediastinum and do not enter the true pleural cavity. An oblique incision is made in the left rectus muscle and peritoneum, extending to the ensiform cartilage. The technical difficulties of adequate exposure of the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of the hiatus is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the incision. The spleen is often very adherent to the posterior part of the diaphragm and hernial opening but usually can be separated from these structures by blunt dissection. It is retracted posteriorly by a specially constructed retractor. In some instances the spleen may be almost drawn into the hiatus and may be so traumatized by separating it from its peritoneal attachments that its removal is advisable.

Herniae through the esophageal hiatus are true herniae and have an hernial sac consisting of abdominal peritoneum which is continuous with the serosa of the stomach. The attachment of the sac to the stomach must be separated and the sac must be either completely removed or permitted to retract into the posterior portion of the mediastinum. I believe that this is one of the most important technical considerations in the surgical treatment of this type of hernia.

After the sac has been removed, the enlarged defective esophageal hiatus is repaired by overlapping the margins of the opening. In many instances it is necessary to elevate the repaired hiatus to a higher position on the esophagus. The latter is a very important procedure in those cases in which there is any shortening of the esophagus or marked elevation of the esophagus into the thoracic cavity (Fig. 4). Repair is usually made to the left of the esophagus but in some cases it is necessary to repair the opening partially both to the right and to the left of the esophagus. In some instances the defect of the esophageal hiatus is posterior, extending to the spinal column. This type requires the overlapping of the margins posterior to the esophagus. In such cases, the condition is often thought to be a herniation through the aortic opening but extending over the aorta there usually is an imperfectly developed, fibrous band which is the margin of the defective esophageal hiatus. The closure is usually made with living sutures of fascia lata, which are removed from the thigh. The overlapped margins of the hernial opening are first stabilized with interrupted linen sutures. The fascia lata is then woven into the tissues by continuous suture and fixed in the tissues with interrupted linen sutures.

In many instances in which the stomach is incarcerated or obstructed, it is impossible to pass a stomach tube into the obstructed loculus of the stomach before operation. In these cases it is advisable to pass a stomach tube

soon after the abdomen is opened, directing the tube into the obstructed portion of the stomach in order to empty the gastric contents before any attempt is made to reduce the herniated viscera, because of the danger of regurgitation and aspiration of gastric contents into the lung. Before closure of the defective esophageal hiatus is completed around the lower part of the esophagus, it is important that a stomach tube of large caliber be passed through the esophagus into the stomach, to aid in the reconstruction of the normal esophageal opening and to prevent constriction of the esophagus by a tight closure. The loose areolar tissue or a small portion of the esophageal wall at the cardia is incorporated into the innermost margin of the closure by a suture of chromic catgut.

The abdomen always should be thoroughly explored for the presence of any other lesion, particularly of the stomach or gallbladder. In some cases it may be necessary to operate upon other associated lesions. However, I do not believe it advisable to carry out any additional surgical procedure at the time of repairing the hernia, unless it is imperative, but it is well to know whether the patient has gallstones or any other lesion in the upper part of the abdomen which might account for subsequent symptoms.

Inasmuch as the surgical treatment of this type of hernia is a repair of an abnormally large hiatus of the esophagus and not a complete closure of an abnormal opening, it is associated with a higher percentage of recurrences than any other type of diaphragmatic hernia, in fact, nine out of ten recurrences in the entire series of 404 cases were of this type of hernia. In four of the nine recurrences, symptoms were severe enough to require a second operation. There were seven deaths (2.2 per cent) in the 320 cases of esophageal hiatus diaphragmatic hernia.

Congenital Short Esophagus.—The surgical treatment of congenital short esophagus with partial thoracic stomach presents an entirely different technical problem from that of esophageal hiatus diaphragmatic hernia. As pointed out previously, the essential consideration in the surgical treatment of esophageal hiatus hernia is that of replacement of the herniated stomach into the abdomen, the removal or obliteration of the hernial sac and the repair and reconstruction of the esophageal hiatus accurately around the esophagus.

Congenital short esophagus with partial thoracic stomach is not a true hernia through the diaphragm, in that the stomach has never been in its normal position below the diaphragm because of shortening of the esophagus. The surgical problem in these cases is that of reconstructing the diaphragm over the elevated portion of the stomach; this can be accomplished if the shortening of the esophagus is not too great. By complete and permanent interruption of the phrenic nerve the diaphragm usually can be elevated from 2 to 5 cm. and then by complete separation of the attachment of the esophagus from the attachments around the esophageal hiatus, from 2 to 3 cm. of the esophagus can be drawn down into the abdomen. The elevation of the diaphragm and the pulling down of as much as is possible of the esophagus into the abdomen permit the esophageal hiatus to be closed around the lower

end of the esophagus, placing what was formerly the thoracic portion of the stomach below the diaphragm.

TRAUMATIC DIAPHRAGMATIC HERNIA

The causation of traumatic diaphragmatic hernia has been considered in an earlier section of this paper.

Traumatic diaphragmatic herniae usually do not present the difficult diagnostic problems which are associated with the esophageal hiatus type of hernia, for the occurrence of the injury leads one to suspect the possibility of a hernia being present. The symptoms associated with this type of hernia progress very rapidly, are severe, and are attributable to the mechanical interference with the function of the herniated viscera as well as to marked interference with function of the heart and lungs. This is due to the fact that there is no hernial sac and the abdominal viscera are in direct contact with the thoracic viscera. The condition in these cases may be more properly termed "evisceration of the abdominal organs into the pleural cavity" rather than a "true hernia." The most marked immediate symptoms are usually those of respiratory and circulatory embarrassment. These herniae are more frequent in adult life and the compensatory cardiac and respiratory reserve usually carries the patient over the acute symptoms if the other associated injuries have not been too great. Later, severe hemorrhage from the gastro-intestinal tract may occur as a result of incarceration or strangulation of the hollow viscera. If the patient survives the acute condition, the later symptoms depend on the viscera involved. The symptoms may consist of obstinate constipation, the occurrence of large quantities of gas in the colon and attacks of partial or complete intestinal or gastric obstruction. The sudden onset of symptoms in cases of traumatic hernia usually is related directly to the injury and there is rarely a question as to the clinical diagnosis. Surgical treatment is demanded because of the danger of cardiac and respiratory failure or because of intestinal strangulation (Fig. 5).

Those types of diaphragmatic hernia which result from inflammatory necrosis of the diaphragmatic muscle caused by subdiaphragmatic abscess or pressure from the drainage tubes used for drainage of empyematic cavities, are considered as traumatic herniae. The symptoms associated with these herniae are often somewhat obscure and in many instances they are unrecognized for a long period of time because the possibility of a hernia is not considered and the symptoms are often thought to be due to the primary illness. In some instances the hernia does not occur in these cases for many months after the patient recovers from the primary illness.

The surgical approach to these herniae may be through the thorax or through the abdomen. For all herniae through the right side of the diaphragm, I prefer the thoracic approach because the large right lobe of the liver interferes with the exposure of the right side of the diaphragm if the abdominal approach is used. In herniae of this side the right lobe of the liver is often incorporated in the hernia and its reduction is more safely accomplished

through the thoracic approach than through the abdominal approach because there is less danger of hemorrhage from injury to the liver.

In all traumatic herniae through the left side of the diaphragm, I prefer the abdominal approach through an oblique left rectus incision. The herniated viscera are usually very adherent to both the abdominal and the thoracic side of the diaphragm and to the structures within the thorax. The adhesions
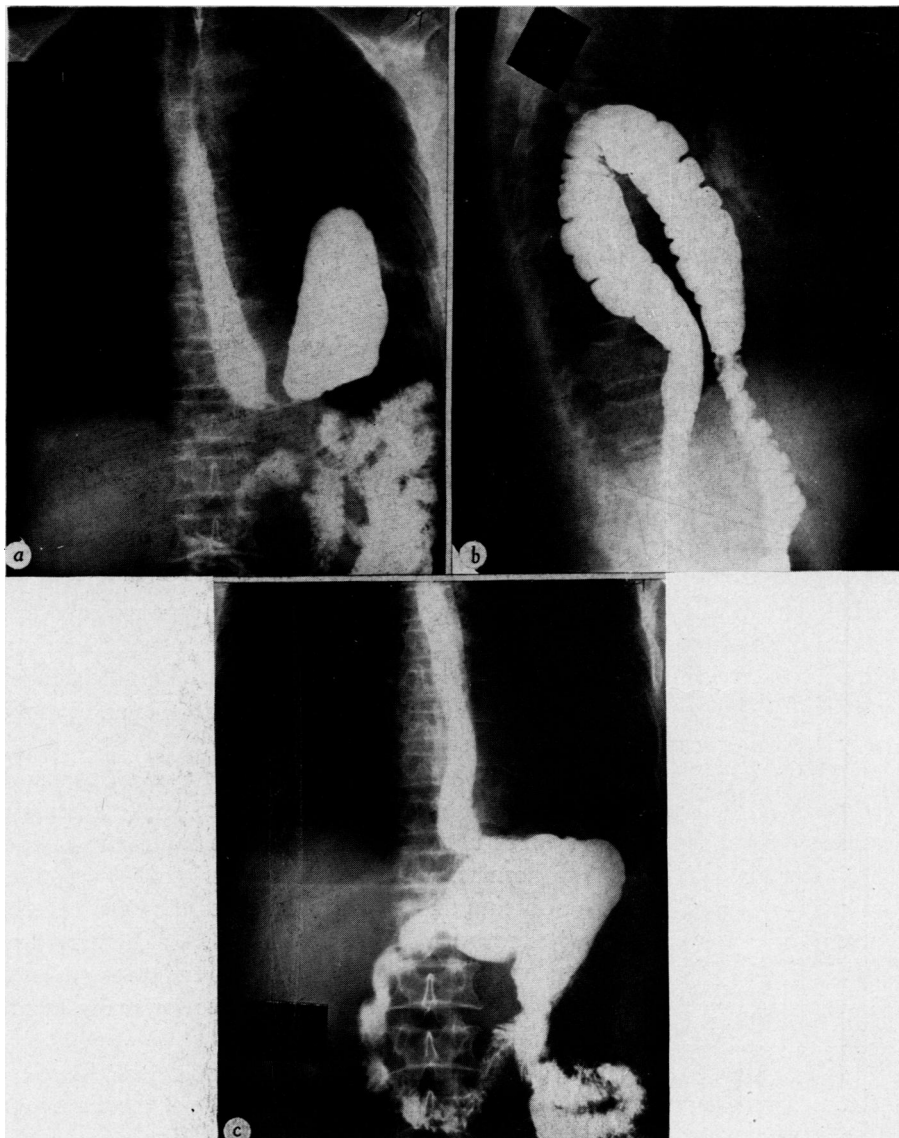

FIG. 5a and b.—Patient, age 73. Large left traumatic diaphragmatic hernia due to an automobile accident. Herniation of the entire stomach, transverse colon and spleen and of several feet of small bowel. The esophagus is in normal position.

c. Same patient three and one-half weeks after repair of laceration in the posterior portion of the left diaphragm which did not involve the esophageal hiatus. The entire stomach is in normal position below the diaphragm.

to the margins of the opening and to the under surface of the diaphragm are often very marked and should be separated first. The adhesions to the structures within the thoracic cavity are separated from below upward by approaching them through the hernial opening. By the abdominal approach this can be accomplished with little danger of injury to the abdominal or thoracic viscera, because the definite relationship of the herniated structures can be established.

In cases in which there has been considerable loss of structure or in which the muscle has been torn from its attachment to the thoracic wall, the defect in the diaphragm should be repaired by fascia lata stabilized with linen sutures. I believe this to be the most satisfactory type of closure in all these cases. In cases of traumatic hernia in which the laceration is confined to the dome of the diaphragmatic muscle, it usually is advisable to repair the opening by lapping the anterior margin over the posterior margin of the opening. When possible, it is advisable to overlap the margins of the opening from 2 to 3 cm. In those cases in which the laceration splits the muscle of the esophageal ring, great care should be taken in repairing the esophageal hiatus. In those cases in which the laceration extends to the margin of the thorax and in which the attachments of the diaphragm are torn from the thoracic wall, the repair is made not only by overlapping the laceration of the leaf of the diaphragm but by resuturing the diaphragmatic muscle to the thoracic wall. This can be accomplished by suturing the diaphragmatic muscle to the intercostal muscles between the ribs. When possible, the diaphragmatic muscle should span two interspaces, being fixed to the intercostal muscles with fascia lata and stabilized with interrupted linen sutures.

In a few instances the relaxation of the diaphragmatic muscle caused by interruption of the phrenic nerve will not be sufficient for repair of the defect. In these cases the diameter of the thorax must be narrowed by resecting the lower ribs by thoracoplasty. It is usually not necessary to resect more than a few inches of the eighth, ninth and tenth ribs at the angles.

Before the abdomen is closed, the herniated viscera should be thoroughly explored, to be certain that there has been no injury to a viscus and that there are no bands of adhesions which will interfere with the function of the abdominal viscera. In cases in which there has been considerable obstruction of the large bowel, it may be necessary to perform appendicostomy or colostomy at the time of operation.

In the series of 55 cases of traumatic diaphragmatic hernia there were no recurrences, and four deaths.

CONGENITAL DIAPHRAGMATIC HERNIAE DUE TO MALFORMATION
AND STRUCTURAL DEFICIENCIES

Congenital diaphragmatic herniae may occur in either the right or the left side of the diaphragm but are much more common through the left side than through the right. The more common herniae of this type are those

through the pleuroperitoneal hiatus, those due to the lack of formation of the posterior portion of the diaphragm and those through the foramen of Morgagni (Larrey's space), anteriorly, more accurately termed subcostosternal herniae.

In the first two types there is rarely, if ever, an hernial sac and the abdominal viscera are in direct contact with the thoracic viscera. In the third type (subcostosternal) there is always an hernial sac, which consists of peritoneum and parietal pleura.

The symptoms of congenital types of diaphragmatic hernia due to structural deficiency in the formation of the diaphragm usually involve multiple abdominal viscera and are often similar to those noted in association with the traumatic types of hernia, as there is rarely a confining sac and the herniated abdominal viscera are in direct contact with the thoracic viscera. The symptoms in these cases are often more severe than those noted in cases of traumatic hernia. Because of the occurrence of the hernia at birth, the respiratory and cardiac symptoms are usually the most severe owing to the marked unilateral alteration in intrathoracic pressure and the occurrence of this derangement of intrathoracic pressure at a time at which the compensatory respiratory and cardiac reserve has not been developed to a sufficient degree to maintain function of these organs. Many infants born with these congenital defects die in the first few hours or days of life. However, if the respiratory and cardiac mechanisms are able to compensate for the presence of these abdominal viscera in the thorax, these patients may live on to childhood or even to adult life without any great amount of disability or symptoms, provided that intestinal or gastric obstruction does not develop. There is less likelihood of obstruction developing in these cases than in the cases of traumatic hernia because there are usually fewer adhesions between the abdominal viscera and the thoracic viscera in the former than in the latter. When the stomach is involved in these herniae, it usually becomes markedly dilated and these patients often have symptoms of partial gastric obstruction. Intestinal obstruction may occur owing to bands of adhesions between the omentum and loops of bowel or owing to inflammatory conditions of the bowel. Inasmuch as there is usually a nonrotation of the right portion of the colon and the cecum, and the appendix is in the left thoracic cavity, appendicitis may develop and produce a very serious hazard to life.

In the surgical treatment of these herniae the approach in the first two types may be either thoracic or abdominal but I prefer the abdominal approach through an oblique left rectus incision. In the third type (substernal) the approach should always be through the abdomen and usually through an oblique right rectus incision or a transverse incision in the epigastrium. I prefer the oblique right rectus incision.

Pleuroperitoneal Hiatus Herniae.—These herniae occur in the posterolateral portion of the diaphragm and are due to failure of fusion of the pleuroperitoneal membrane and the septum transversum. The defect is usually triangular with the apex toward the median portion of the diaphragm.

The defect usually extends to the thoracic wall but occasionally there is an imperfectly developed band of muscle tissue extending along the thoracic wall. These herniae do not have an hernial sac and there is a direct communication between the abdominal and the thoracic cavity.

The most common abdominal viscera involved in this type of hernia are the colon and the small bowel. There may or may not be herniation of the
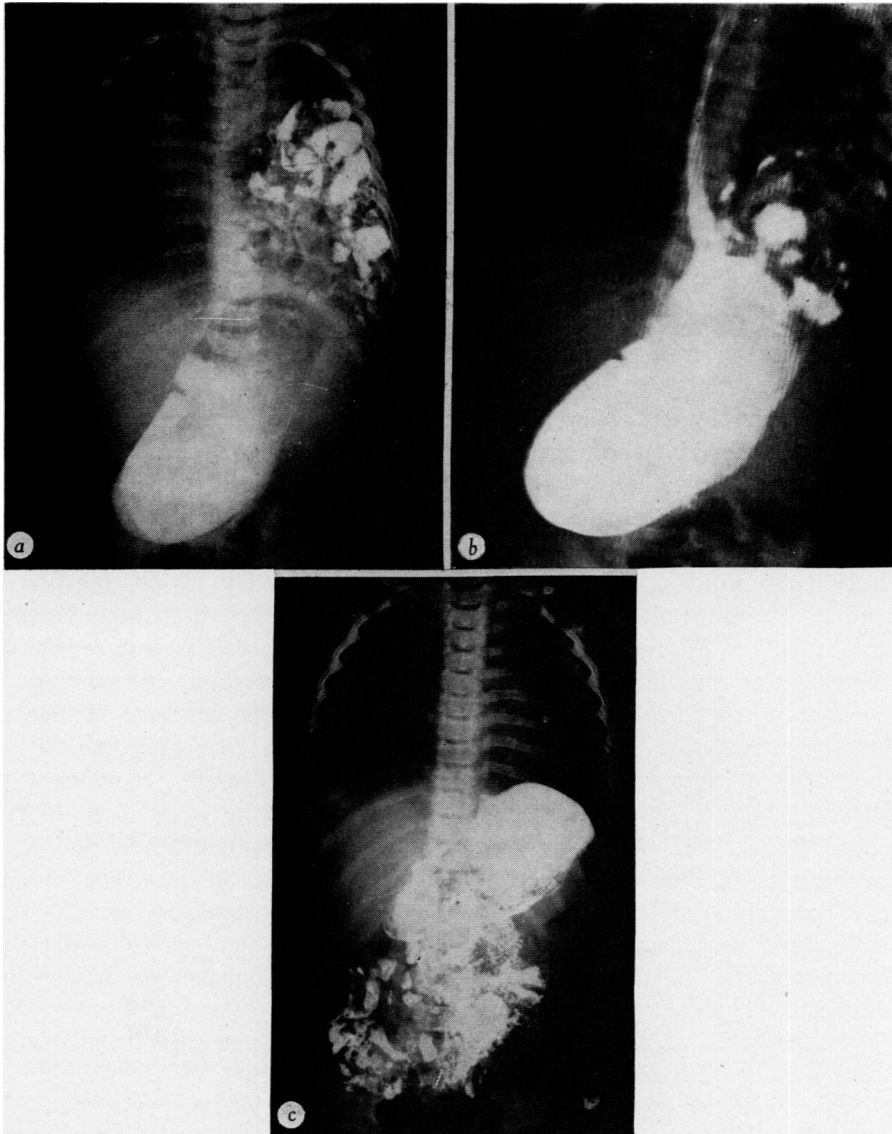

FIG. 6a and b.—Patient, age four months. Pleuroperitoneal hiatus hernia with herniation of many loops of large and small bowel in the left thoracic cavity. Marked displacement of the ‚mediastinum and heart to the right. The stomach is dilated and below the diaphragm.

c. Same patient on reexamination one year after operation. The stomach and the intestines are entirely below the diaphragm, which is of normal contour and position. The heart and the mediastinum are in normal position. Both pulmonary fields are normal.

spleen and stomach. There is often a failure of rotation of the colon and the entire right side of the colon (appendix and cecum), the terminal part of the ileum and all of the small intestines to the jejunum are involved in the hernia.

This type of hernia is said to be the most common of the congenital types of hernia due to structural deficiencies. These herniae are present at birth. Many of the infants suffering from them die in the first few hours or days of life because of respiratory and cardiac embarrassment and before surgical intervention can be instituted. In treating those infants who are able to survive in spite of the altered intrathoracic pressure and thoracic visceral relationship, surgical intervention should be instituted as soon as possible because of the danger of intestinal obstruction. If they are able to maintain nourishment, it is well to delay operation for two to three months in order to permit some development of their accessory respiratory mechanism. If operation is delayed for a long period, the abdominal viscera will have lost their right of residence in the abdomen in that the abdominal cavity will not have developed sufficiently to contain them and there will be marked increase in the intra-abdominal pressure when the viscera are replaced into the abdomen (Fig. 6).

In repair of the smaller herniae of this type the opening can be closed without utilizing interruption of the phrenic nerve. On the other hand, in repair of the larger herniae interruption of the phrenic nerve is a necessary procedure. The opening is completely closed by overlapping the margins from 2 to 3 cm. If the patient is an infant, this closure is made with interrupted silk sutures. Before the opening is completely closed, the air is aspirated from the pleural cavity by inserting a catheter connected to a suction apparatus. At the time of withdrawal of the catheter the last suture is tied, completely closing the communication between the thorax and the abdomen.

One of the chief dangers associated with the repair of these herniae is marked alteration of intrathoracic or intra-abdominal pressure. It is very important in these cases that the respiratory function be maintained by positive pressure during the operation and that at the completion of the operation negative pressure be obtained and secured in the thoracic cavity. A roentgenogram should be taken at the completion of the operation to see that there is no shift of the mediastinum due to the pneumothorax. I do not permit the patient to leave the operating table until I have seen the roentgenogram. If there is any shift of the mediastinum, more air is withdrawn to maintain the mediastinum in the midline.

In the series of nine cases of hernia through the pleuroperitoneal hiatus there were no recurrences and three deaths.

Congenital Absence of the Posterior Portion of the Diaphragm.—This type of hernia is due to failure of the formation of that portion of the diaphragm which is derived from the pleuroperitoneal membrane. The defect is in the posterolateral portion of the diaphragm and usually extends from the eighth rib posteriorly and medially to the esophageal hiatus. These

herniae usually do not have a sac but there may be an imperfectly developed enveloping membrane of peritoneum and omentum which simulates a sac. These herniae may be considered an enlargement of the foregoing pleuroperitoneal type in that the essential difference is a much more extensive congenital defect in the formation of the diaphragm. There are more abdominal viscera involved in the hernia in that these herniae always contain the stomach and spleen as well as the large and small bowel. Occasionally the left kidney is elevated above its normal level into the pleural cavity (Fig. 7).
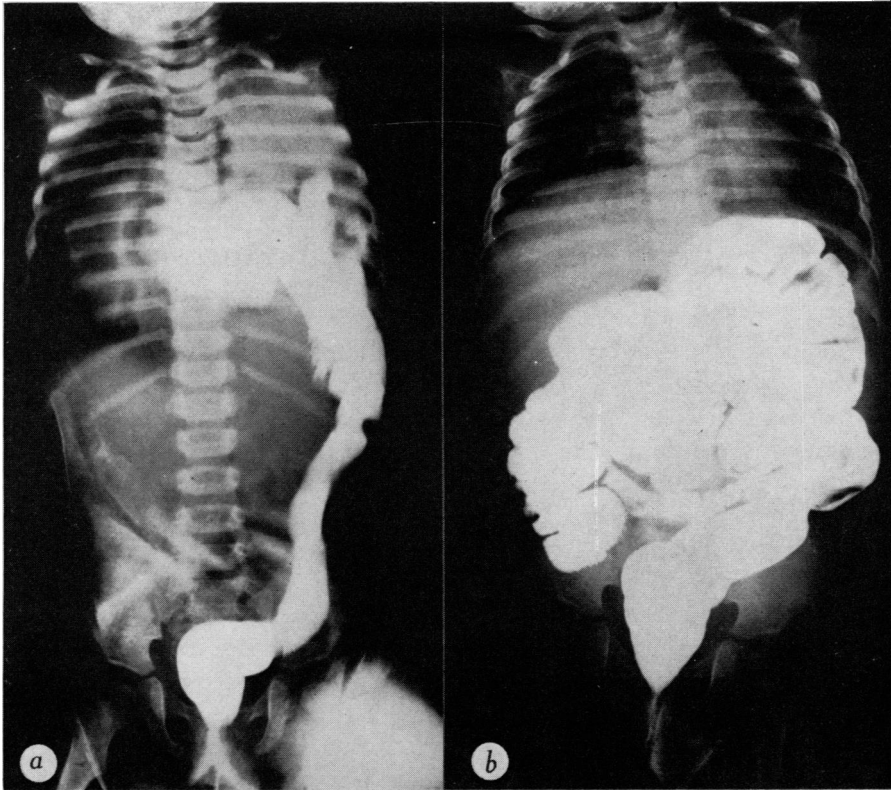

Fig. 7a.—Patient, age six months. Congenital absence of a portion of the diaphragm. Herniation of the entire right portion of the colon and cecum (small bowel and stomach), into the left thoracic cavity. Complete collapse of the left lung. Marked displacement of the heart and mediastinum to the right.

b. Same patient one month after reconstruction of the defective diaphragm (with fascia). Entire colon (and other herniated viscera) below the diaphragm. The left diaphragm, the heart and the mediastinum are in normal position. Pulmonary fields normal.

Not only do the surgical problems associated with these herniae involve all of the problems of the pleuroperitoneal herniae as far as altered intra-abdominal and intrathoracic pressure is concerned but in addition there is the problem of closing this large gap with the diaphragmatic muscle that is present and of reconstructing the attachment of the diaphragmatic muscle to the thoracic wall. In some instances the posterior perirenal fascia may be utilized in obtaining this closure and fixation to the thoracic wall. If the

gap is not too great, this can be accomplished by complete, permanent interruption of the phrenic nerve. If the defect is too large to permit the relaxed diaphragm to span this gap, it is necessary to shorten the diameter of the diaphragm by extrapleural rib resection.

In 12 cases herniae were due to congenital absence of a portion of the diaphragm. There were one recurrence, and two deaths.

Subcostosternal Hernia through the Foramen of Morgagni (Larrey's space).—Herniation of abdominal viscera through regions of deficiency of muscle in the anterior portion of the diaphragm close to the sternum has received various names, such as diaphragmatic hernia through the foramen of Morgagni, or through Larrey's fissure or space, and also substernal, retrosternal, parasternal or anterior diaphragmatic hernia. Inasmuch as these herniae usually occur to either side of the anterior midline of the diaphragm, if an anatomic term is to be used, it would be preferable to designate them as subcostosternal diaphragmatic herniae.

There is some difference of opinion as to whether these herniae should be classified as congenital or acquired herniae. It is impossible to explain their occurrence on a basis of faulty fusion or improper disposition of the embryonic mesodermic elements which go to form the diaphragm, as this anterior portion of the diaphragm is derived from the septum transversum only. But the consistency of the location of the hernial opening, the fairly constant relation of the neck of the hernial sac to the round and falciform ligaments of the liver and the frequency with which the hernial sac protrudes into the right side of the thoracic cavity at the same point of entrance at the cardiophrenic angle, as well as the often associated nonrotation of the right portion of the colon, all strongly suggest a fundamental embryologic basis for these herniae. These herniae are essentially direct herniae through a congenital defect in the structure of the diaphragm or a faulty attachment of the diaphragm to the sternum and costal cartilages. The constant presence of a peritoneal sac shows that the peritoneum had closed off the abdominal cavity from the pleural cavity before the actual herniation of the abdominal viscera occurred.

Subcostosternal diaphragmatic hernia is one of the two types of diaphragmatic hernia, in my experience, which have an hernial sac. The other type of diaphragmatic hernia which has an hernial sac is that through the esophageal hiatus. It is interesting that subcostosternal hernia is probably the rarest type of diaphragmatic hernia and esophageal hiatus diaphragmatic hernia is the most common; both are essentially congenital in origin but are rarely present at birth, and occur in most instances in later life because of increased abdominal pressure on a congenitally defective diaphragm.

The abdominal viscera usually involved in the hernia are the colon, omentum, ileocecal coil and rarely the stomach (Fig. 8).

The subjective symptoms associated with these herniae are often indefinite and depend on the type and amount of abdominal viscera involved in the hernia. They are usually due to impairment of respiration and intestinal

obstruction. Among them are dyspnea, cough and attacks of partial intestinal obstruction and thoracic and abdominal pain.

In the cases in which hollow viscera are involved in the hernia, symptoms occur which suggest the possibility of a hernia or at least the necessity of a roentgenologic examination of the intestinal tract which will determine whether a hernia is present. The cases in which omentum only is involved in the hernia present a much more difficult clinical problem in arriving at a
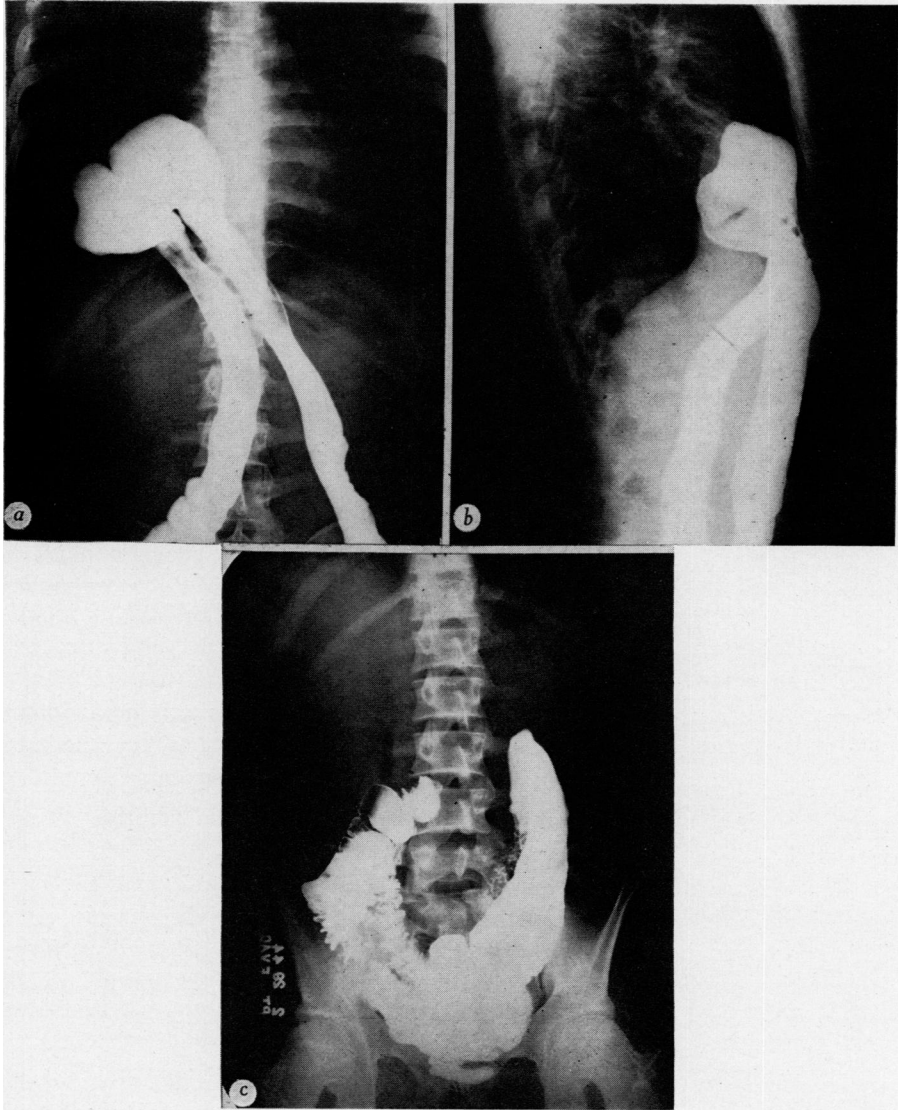

Fig. 8a and b.—Patient, age 35. Subcostosternal (foramen of Morgagni) diaphragmatic hernia. Herniation of transverse colon with marked displacement of splenic and hepatic flexures into the right anterior thoracic cavity at the cardiophrenic angle.

c. Same patient one month after repair of hernial opening in the anterior diaphragm. The entire colon is below the diaphragm.

definite diagnosis. The subjective symptoms in the latter group are entirely thoracic as a result of mechanical interference with respiration and expansion of the lungs. These symptoms suggest a primary pulmonary lesion and direct the clinical investigation to roentgenologic study of the thorax. The roentgenologic findings of an increased density in the pulmonary field justify the clinical diagnosis of a primary intrathoracic lesion which may be thought to be an intrathoracic tumor. This erroneous clinical diagnosis is particularly likely to occur if there are no subjective symptoms even to suggest that an abdominal condition may be present and, even though the gastro-intestinal tract is examined roentgenologically, no lesion is demonstrated as no abdominal hollow viscera are involved in the hernia.

One of the most important clinical considerations of this type of hernia is the possibility of regarding the patient's condition as due to an intrathoracic tumor in the cases in which the omentum is the only abdominal structure involved in the hernia.

The treatment of these herniae is surgical closure of the abnormal opening in the diaphragm after replacement of the abdominal viscera into the abdomen. I prefer an abdominal approach through the upper part of the right rectus muscle because the opening in the diaphragm is very accessible and the abdominal contents of the hernia are more safely and easily reduced from the abdominal than from the thoracic side of the diaphragm as the true relationship of the herniated viscera to the hernial sac can be accurately determined.

The method of closure of the neck of the sac and of the defect in the structure of the muscle of the diaphragm depends on the size and character of the opening. Small linear openings may be closed by overlapping the margins. Larger transverse openings extending beneath the sternum are best closed by suturing the anterior margin of the diaphragmatic muscle defect to the posterior sheath of the rectus muscle and to the anterior thoracic wall.

The most satisfactory material for closure of the opening is living suture of fascia lata removed from the thigh and stabilized in the tissues with silk. The round ligament of the liver can be incorporated in this closure to strengthen it as well as to reëstablish its position on the anterior abdominal wall.

The closure of the large openings is facilitated by paralyzing the right side of the diaphragm by temporary interruption of the right phrenic nerve. This procedure, however, is not necessary in the closure of small openings. Preparation can be made to interrupt the phrenic nerve in the supraclavicular region after exploring the opening and determining whether or not interruption is necessary.

In this series of 404 cases of diaphragmatic hernia, eight were of the subcostosternal type. There were no deaths or recurrences following their operative treatment.

In Table II the surgical procedures and operative results in the entire series of 404 cases are given.